PAWTUCKET RIVER, RHODE ISLAND.

LETTER

FROM THE

CHIEF CLERK OF THE WAR DEPARTMENT,

TRANSMITTING

A report upon the past improvement and present condition of Pawtucket River, Rhode Island.

JUNE 19, 1874.—Referred to the Committee on Commerce and ordered to be printed.

WAR DEPARTMENT, *June* 5, 1874.

The chief clerk of the War Department, in the absence of the Secretary of War, has the honor to transmit to the House of Representatives, for the information of the Committee on Commerce, letter of the Chief of Engineers, dated the 2d instant, and copy of report of Major G. K. Warren, Corps of Engineers, on the past improvement and present condition of Pawtucket River, Rhode Island.

H. T. CROSBY,
Chief Clerk.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., June 2, 1874.

SIR: I beg leave to submit for your consideration a copy of a communication received from Major G. K. Warren, Corps of Engineers, inclosing a report on the past improvement and present condition of Pawtucket River, Rhode Island. He thinks the expenditure of the appropriation for the improvement of Pawtucket River should not be limited to dredging the shoals above the bridges; but that, as the balance in his hands is not more than sufficient for dredging these shoals, if possible the bridge companies should be required to remove the obstructions they have created in the vicinity of their bridges.

He draws attention to the obstruction to navigation and to the free flow of the tide caused by the three bridges on the Pawtucket, and desires to be informed whether there is not a legal remedy to compel the bridge companies to restore the water-way to a proper natural width, and to control the bridging of the river in the interests of commerce. One of these bridges, at present a serious obstruction to commerce, is about to be rebuilt, and its future location and plan should be subject to the control of the United States.

In view of these representations of Major Warren, I would respectfully suggest that the accompanying papers be transmitted to Congress for such action as may be deemed proper.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Brigadier-General and Chief of Engineers.

Hon. W. W. BELKNAP,
Secretary of War.

IMPROVEMENT OF PAWTUCKET (SEEKONK) RIVER, RHODE ISLAND.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., May 6, 1874.

GENERAL: I have the honor to submit the accompanying report of Assistant H. A. Bentley, civil engineer, on the past improvement and present condition of the Pawtucket (Seekonk) River, Rhode Island. This report is accompanied by a map made from a survey conducted during the season of 1873. It is on a scale of 200 feet to the inch, and shows not only the condition of the channel, but also the positions and structure of the bridges across it. To these latter I wish to ask special attention. Mr. Bentley's report is as concise as the matter it contains will admit. There is, first, a history of the former improvements; second, an account of this last survey; third, a presentation of the points where further dredging is most needed; fourth, a history of the building and rebuilding of the bridges, and the legal authority for building them; fifth, a consideration of the obstruction these bridges cause to the tidal currents, and their influence in decreasing the height of the tide at the city of Pawtucket wharves; sixth, future improvements at bridges.

The points for special notice brought out under these different heads are as follows:

First, in regard to dredging already done. The dredging done previous to the last appropriation—that of $10,000, approved March 3, 1873—had made a channel-way 75 feet wide and 7 feet deep at mean low water. It had been conducted under four different appropriations, and with the last one it was found necessary to re-dredge at places which had become filled since the first dredging. One object of the survey was, therefore, to determine the places where liability to reform shoals existed, so that by making enlarged and deeper channels at these places we might secure the requisite draught, even after considerable refilling had taken place. Mr. Bentley's report clearly points out these; and if our future operations are to be confined to dredging, as they have been, I would recommend simply carrying out his suggestions with the funds now on hand.

But if something can be done at the bridges, I think it more important that it should be done there than altogether confined to the shoals above them. Before recommending that the last appropriation should be expended for this purpose, I would like to know what can be exacted from the bridge company. I beg here to refer directly to Mr. Bentley's report, page 14, on "the bridges." Their history and condition, the authority for building them, and what should be done, is stated fully. At the Red bridge an expenditure of about $675 is required to remove stone from the east opening of the pivot-draw. It is now so obstructed that it is useless to navigation; and if the other draw-opening should be closed by a sunken vessel, all navigation of the river would be suspended. If the bridge company cannot legally be com-

pelled to open properly this east draw-space, I would recommend that the present appropriation be used for that purpose. Under the heading "obstructions to tidal flow," &c., Mr. Bentley makes further estimates for dredging between the piers of the Red bridge, at an estimated cost of $8,085. This latter expenditure the means in our hands would not justify us in making, as it would prevent necessary dredging on the shoals above. I wish it would be ascertained, by proper reference, whether there is not legal remedy to compel this bridge company to restore the water-way to a proper natural width.

The Washington bridge is in so bad a condition that it is expected to soon rebuild it; but it is a very serious obstruction to navigation, and it is not at all likely that, when rebuilt, it will be suited to the wants of navigation, unless some control is exercised over it by the General Government. The present railroad bridge might have been, and should have been, better located.

I deem it, therefore, a matter of importance that some steps should be taken—what ones, exactly, I do not know—to control the bridging of the Pawtucket River in the interest of navigation; and unless such control is acquired by the General Government, it seems to me out of place to further regard the improvement of the Pawtucket River as a public one, or that that estuary is longer a navigable water of the United States.

A small sketch in Mr. Bentley's report shows the location of the bridges.

I will await an answer to this communication before taking any further measures toward dredging in the Pawtucket River.

Very respectfully,

G. K. WARREN,
Maj. Engineers, Bvt. Maj. Gen. U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers U. S. A., Washington, D. C.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., April 4, 1874.

GENERAL: I have the honor to submit the following report on the improvement of the Pawtucket or Seekonk River, Rhode Island. This will be a history of improvement prior to 1873, an account of the survey in 1873, a description of shoals requiring dredging, a history and description of the bridges, and their effects on navigation and tides, with a statement of improvements required.

HISTORY OF IMPROVEMENTS.

The first appropriation for the improvement of this river was made in 1867, when $17,000 were allotted for the work; the money was expended in dredging the channel, above High Hill, with the purpose of making it 75 feet wide, and 6 feet deep at mean low water. The general depth in the channel of the river above High Hill, at this time, was 5 feet at mean low water. The dredging done was at the bars known as High Hill Bar, Swan Point Bar, and Ingrahamville Bar. This improvement was carried on under Col. D. C. Houston, Major United States Engneers.

By act of Congress, approved July 11, 1870, an additional appropriation of $8,000 was made for this improvement. This money was expended, under your direction, in making a channel 75 feet wide and 7 feet deep at mean low water, from Thornton's wharf, Pawtucket, to Bass Rock. The depth of water to be made was changed from 6 to 7 feet, because of the impracticability of making so light a cut as a depth of 6 feet required.

By act of Congress, approved March 3, 1871, $7,000 were appropriated for the continuance of the improvement; this money was expended in connecting the channels dug in 1867, at High Hill and Swan Point, by dredging a channel 75 feet wide and 7 feet deep between them; and in dredging the bar immediately above Swan Point. An examination of the channels dredged in 1867 proved that the general depth in them was 7 feet at mean low water, so that the dredging done in 1871 opened a channel of the

required width and depth up to a point half way between Swan Point and Bishop's Point. A report, giving the details of the work done from 1870 to 1872, may be found in report of Chief of Engineers for 1872, page 818.

By act of Congress approved June 10, 1872, an appropriation of $10,000 was made for this river. After the usual advertisements for bids, a contract was made with Mr. E. M. Payn, of Albany, N. Y., for dredging and removing material, at the rate of 32½ cents per cubic yard. Dredging was commenced under this contract August 8, 1872, at the place where work was stopped the previous year on account of the exhaustion of the appropriation.

The general plan adopted for the work was to continue the channel 75 feet wide and 7 feet deep up to Dunnell's wharf, there to connect with the channel dredged under the appropriation of 1870.

It was found necessary to redredge a greater portion of the channel opposite Ingrahamville that had been dredged in 1867; also the bar at Dunnell's wharf—the latter place had filled in since 1871. Some dredging was also done on the bar opposite High Hill. This contract was completed May 12, 1873, 26,073 cubic yards of sand, gravel, and mud having been removed from the channel and placed on the adjoining flats.

By an act of Congress approved March 3, 1873, another appropriation of $10,000 was made for this work. The previous appropriations were supposed to have given the channel the required width and depth; it was, therefore, decided by you to have a survey made of the river, to ascertain how the available money might be expended, so as to give the greatest benefit possible to navigation.

SURVEY IN 1873.

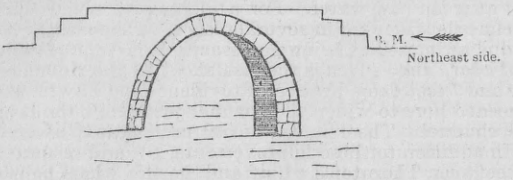
In pursuance of instructions received, I proceeded to Pawtucket, May 14, and commenced the survey by covering the entire river, from Pawtucket to Fox Point, Providence, with a system of triangles, in which each angle was measured three times. A connection was made with the survey of Providence River, made in 1872. The surveying party was then organized, and commenced the traverse May 19, starting at S. Grant & Co.'s old coal-dock, and running down the west bank of the river to India Point wharves, Providence, where the party crossed the river. A line was then run up the east bank from Station D, Providence River survey, to Clapp's chemical works, Pawtucket. The traverse lines were connected with the primary triangulation points, either by deflection and distance, or by making them stations of the line. The total length of traverse line run was about ten miles.

On the 2d of June, the party commenced locating soundings. The position of each sounding was fixed by two angles, read from triangulation-stations which formed the ends of a known base.

The soundings were taken mostly in the channel of the river, the flats on either side being of so uniform a depth that but few soundings were necessary to give a true showing of them.

Each of the three bridges crossing the river were surveyed, data being obtained for elevations of them. Soundings were carefully located on their axes and around each pier.

Tidal observations were made for a lunar month previous to the survey, to establish a mean low-water plane; these observations were made at Butler Hospital Dock, from April 22 to May 19, inclusive; day-tides only being observed. The mean rise and fall of tide during that month was 4.46 feet. Mean low-water plane established by these observations is referred to a bench-mark on stone arch over road leading back from the wharf, and about 300 feet from it. This bench-mark is 55.794 feet above mean low water. Below is a sketch showing its location.



Tide-gauges were established at Smith's wharf, Dunnell's wharf, Bishop's Point, Red bridge, and Washington bridge, for the reduction of soundings made in their vicinity. The zeros of these gauges were referred to the plane of mean low water, as established at Butler Hospital Dock, by making simultaneous observations at each gauge at low water, and assuming that the low water at each of these gauges bore the same relation to mean low water that it did at Butler Hospital Dock, the place where the mean low-water plane was established.

Observations at Providence, extending from May 22 to December 28, 1873, were obtained from a record kept by the Providence City Water-Works. The mean rise and fall of tide during this time was 4.548 feet, or 0.088 feet more than that given by the observations at Butler Hospital Dock for one month only. This slight difference would show that the latter observations were taken at a time when the river was only ordinarily affected by winds or other disturbing influences.

Observations to establish a mean low-water plane were made at Bishop's Point for a lunation in October and November, 1872. These observations give the mean rise and fall of tide as 5.04 feet, being 0.58 feet more than that given at Butler Hospital Dock, and 0.492 more than at Providence. The simultaneous observations taken show that the mean low water here, as established in 1872, is 0.2 feet lower than that at Butler Hospital wharf. The probable cause of this difference is, that the observations in 1872 were taken at a time when the prevailing winds very materially affected the tides, so that these observations do not show the state of the river as it is at ordinary seasons, as well as those taken at Butler Hospital dock in 1873; and for this reason the latter plane was used for the reduction of soundings. Mean low water at Bishop's Point is referred to a bench-mark on the point, which is a cross cut in the river-face of a boundary-stone, the intersection of the lines forming the cross being the mark. This mark is 6.42 feet above the mean low-water plane established here in 1872, and 6.22 feet above the mean low-water plane established by simultaneous readings.

The observations at the above-mentioned places are appended to this report.

[The map of this survey, platted to a scale of 200 feet to the inch, on which is shown sections of bridges and profiles of river-bottom along their axes, is submitted herewith.]

SHOALS REQUIRING DREDGING.

From the map of the survey, it appears that the channel heretofore dredged and supposed to be 75 feet wide and 7 feet deep at mean low water, is in some places considerably less than this in width and depth. These places, commencing in the upper part of the river, are Thornton's Bar, Dunnell's Bar, Bass Rock Bar, Swan Point Bar, and Butler Hospital Bar. The following is a short description of each, together with estimates for removing that part of them lying in the channel:

Thornton's Bar lies about 300 feet below Thornton's lower wharf. The 7-foot channel here is only 40 feet wide. It was dredged in 1871 to a width of 75 feet, but has since filled in. To redredge this to the required width would require the removal of 1,200 cubic yards of sand and gravel.

Dunnell's Bar is immediately below Dunnell's wharf. A channel has been dredged through this bar twice since 1870, and there is now less than the 75 feet width with the required depth of 7 feet at mean low water. The formation of this bar is probably due to the fact that the river, which above this point is confined to a comparatively narrow channel, here expands to nearly double its former low-water area. The ebb tide in that part of the river above this bar is quite strong, and probably brings down a large amount of material, of which a large proportion is deposited at this place because of the sudden decrease in the velocity of the current caused by the increase in section. It is recommended that the dredging be carried to 9 feet at mean low water at this place, in order to give an improvement that may at least last for a few years. This, it is estimated, will require the removal of 1,800 cubic yards of sand and gravel.

Bass Rock Bar.—The removal of 500 cubic yards of sand and gravel will be sufficient to give the required width and depth to the channel here, as it only needs dredging for a short distance on the east side, immediately below Bass Rock.

Swan Point Bar.—This is the most troublesome shoal in the river. The channel, running nearly straight for a mile and a half above, here makes a turn to the right, at an angle of about 45°. The effect of this turn is to form an eddy, which probably deposits the material forming the bar. It is recommended that this bar be dredged to a depth of 9 feet at mean low water. For a distance of about 1,500 feet below this shoal the channel needs widening in several places. The removal of 11,000 cubic yards of sand and mud is estimated as being necessary for the improvements at this locality.

Butler Hospital-wharf Bar.—This is the last shoal in the river obstructing the channel, 75 feet wide and 7 feet deep, between Providence and Pawtucket. A small amount of dredging is needed here to widen the channel just below the hospital wharf, on the west side of the channel. The removal of 500 cubic yards of mud will give the required width. In addition to these improvements, I would recommend that the channel of the river between Thornton's wharf and Smith's wharf be widened from 75 feet to 140 feet, because of the close proximity of the channel here to the wharves. Vessels unloading at Thornton's wharf obstruct the channel so much that it is almost impossible for other boats to get by them. This improvement, it is estimated, would require the removal of 3,000 cubic yards of sand and gravel. It includes the removal of a small point extending into the channel opposite Thornton's lower wharf.

The following is a summary of dredging required, with its estimated cost:

Thornton's Bar, 1,200 cubic yards sand and gravel.

Dunnell's Bar, 1,800 cubic yards sand and gravel.

Bass Rock Bar, 500 cubic yards sand and gravel.
Swan Point Bar, 11,000 cubic yards sand and mud.
Butler Hospital wharf, 500 cubic yards mud.
Thornton & Smith's Bar, 3,000 cubic yards sand and gravel.
Eighteen thousand yards, at 33 cents per yard, would cost $5,940; add 10 per cent. for engineering and contingencies gives the total cost $6,534.

THE BRIDGES.

There are three bridges crossing this river. The first, or upper bridge, is known as the Red or Central Bridge; the second, about three-fourths of a mile below, as the Washington Bridge; and the last, about 250 feet below this, as the India Point railroad-bridge. The first two are highway-bridges.

The following is a brief history of each of them from the time of their first being built:

Red, or Central Bridge.—The first bridge at this location was built in 1793. It was a wooden truss, resting on six pile-piers, and having a draw-span on the west side, with one opening 24 feet in length. It was carried away by a gale in 1807, and was rebuilt in the same year.

The piles on which the former superstructure rested having decayed so as to be unsafe, piers of rubble masonry were built around them.

In 1859 the general assembly of the State of Rhode Island passed an act requiring the draw-openings in the bridges over the Seekonk River to be made 38 feet wide in the clear. The draw of this bridge was widened in accordance with this law.

The entire bridge was rebuilt in 1871, the draw being located in the center, with spans of 80 feet in the clear on either side of the pivot-pier, the ends of the span resting on stone piers, which are connected with the shore by spans 88, 92 feet long. The piers are built of laid masonry, resting on the foundations of the old piers, except the pivot-pier, which rests on a pile foundation. The superstructure is of iron.

The building of this bridge was authorized by an act of the State assembly of Rhode Island, passed May 28, 1869. Section 2 of this act, in relation to draw in said bridge, says:

"To have a draw-bridge of not less than 80 feet in width on each side of said draw when opened, and located in the main navigable channel of the river for the safe and convenient passage of all vessels navigating said river through said draw."

The draw of this bridge was not located in strict accordance with this law, the then main navigable channel of the river being on the west side where the old draw-span was located.

The present openings of the draw are nearly in a line connecting the deep water above and below the bridge, so that passing vessels can straighten out before entering the bridge, and for this reason the draws as now located are an improvement on the location as provided by the law just quoted.

These draw-openings are probably in what was the main channel of the river; but to protect the piers of the old bridge a large amount of stone was thrown in about them from time to time, until the depth of water in that part of the river where the draw-spans now are was but 4 feet at mean low water. When the present bridge was erected the west draw-opening was dredged to a depth of 10 feet at mean low water; the east opening is still obstructed by riprap, and is useless to navigation.

If the draw-spans had been located in strict accordance with the law, and had the company done the same amount of dredging, we should have had two navigable draw-openings instead of one; of which the east opening would have been in the same location as the now navigable draw-span. If the present opening should in any way be obstructed, the navigation of this river must stop until such obstruction is removed.

The amount of material to be removed from the east opening to give 12 feet at mean low water is about 350 cubic yards, which, at $1.75 per cubic yard, would cost $612.50; adding 10 per cent. for contingencies, gives the total cost $673.75. Inasmuch as the bridge company authorized the location of the draw in its present position, and also authorized the throwing in of the material forming the obstructions here, it would seem to devolve on them to bear the expense of dredging this material out.

The low-water area or axis of this bridge before piers were built was 3,752 square feet; the area occupied by foundations of old and foundations and piers of new bridge is about 2,462 square feet. The high-water area was 5,298 square feet; area occupied by piers, &c., 2,619 square feet.

Washington Bridge.—This bridge was built in 1793 on six pile-piers, with a draw, having one opening, 24 feet in length, on the east side of the river. This bridge was carried away by a storm in 1807, and was rebuilt in that same year. It was carried away again and rebuilt in 1815. At this time the three piers west of the draw were built up of rubble masonry in the same manner as was done in the Red Bridge. These piers settled, so as to be entirely out of sight before the new superstructure was ready to be put up. More riprap was thrown in on top of the submerged piers, and piers

built on top of this. These piers stood until 1867, when one of them toppled over. This was supposed to have been caused by oystermen bringing up the stone forming the foundation of the pier while fishing about the bridge.

This pier was rebuilt, and the three remaining pile-piers built up similar to the rest. About this time an act was passed by the general assembly prohibiting oyster-fishing within a certain number of feet of the bases of the piers.

The draw-opening of this bridge was increased to 38 feet about the year 1859, in accordance with the law to that effect.

The present superstructure is a wooden lattice-truss, built on the rubble piers heretofore described. The draw span is of the same length as in 1859, (38 feet.) The general depth of water in the draw-span is 6.6 feet at mean low water; the greatest depth is 9 feet.

The low-water area on the axis of the bridge before the piers were built was about 3,697 square feet. The area occupied by the foundations and piers of the bridge is about 2,054 square feet. The high-water area was about 5,587 square feet. Area occupied by piers, &c., 2,586 square feet.

India Point Railroad Bridge.—This bridge is about 250 feet below Washington Bridge. The first bridge built here in 1835 was located about 40 feet above the present one. It rested on three piers composed of oak piles covered with copper to protect them from the "terredo navalis." These piers lasted until 1857, when they had to be renewed; these in turn decayed, and in 1867 were substituted by the Cushing patent iron-cylinder pier, on which the present bridge rests.

The draw-openings of the old bridge were located on the east side of the river. The draw at first had but one opening. In 1858 a new draw was built, having two spans 38 feet wide in the clear.

The act authorizing the construction of the present bridge, built in 1867–'68, passed the general assembly in 1866. This act provided that the draw of the bridge should be at least 60 feet in width, and that the proposed bridge and draw should be located in a manner satisfactory to Robert Sherman, esq., of Pawtucket. The first condition has been carried out; as to the latter, I am not informed.

This bridge is 396½ feet long, divided into three spans and a draw. Commencing on the west side, there is first a span of 113 feet; next, one of 108½ feet; next is the draw, 154 feet, with openings of 60 feet in the clear; and last, a short span of 20¾ feet, one end of which rests on a stone pier, (the only one in the bridge;) the other end rests on the abutment.

The superstructure is a Howe truss. The low-water area on axis of bridge before piers were built was 5,148 square feet; area occupied by piers, 683 square feet; high-water area was 6,849 square feet; area occupied by piers, &c., 873 square feet. The piers of this bridge, as regards economy of area obstructed by them, are as good as any that are used, and present a marked contrast with the piers of other bridges crossing this river.

An act in relation to this bridge, passed by the general assembly in 1868, says, section 2: "Said draw-tender shall at all times during the season of navigation cause the draw of said bridge to be opened for the passage of boats or vessels, on proper signals, to be arranged by said company; but the draw of said bridge shall not be opened within ten minutes of the table time for the passing of any train or locomotive over the same until after the arrival and passing of any train due; and any boat or vessel ready to pass shall not be detained beyond the time provided for in this section."

SEC. 4. "Masters of vessels passing said draw shall so place their buoys, warping-lines, cables, or anchors as neither to interfere with other vessels nor obstruct the bridge, only as they may be authorized by the draw-tender, and without the consent of said draw-tender not more than one vessel at any one time shall be towed through said draw by any steam-tug or other motive-power."

The latter part of section 4 of this act gives to the draw-tender authority to regulate the size of all tows passing through this bridge, so that a man appointed draw-tender, while he may be utterly ignorant of all matters pertaining to navigation, can insist on the disposition of each tow in such a manner as to be a source of expense and trouble. I have never heard of any undue interference on the part of the draw-tender, and only mention this as a contingency.

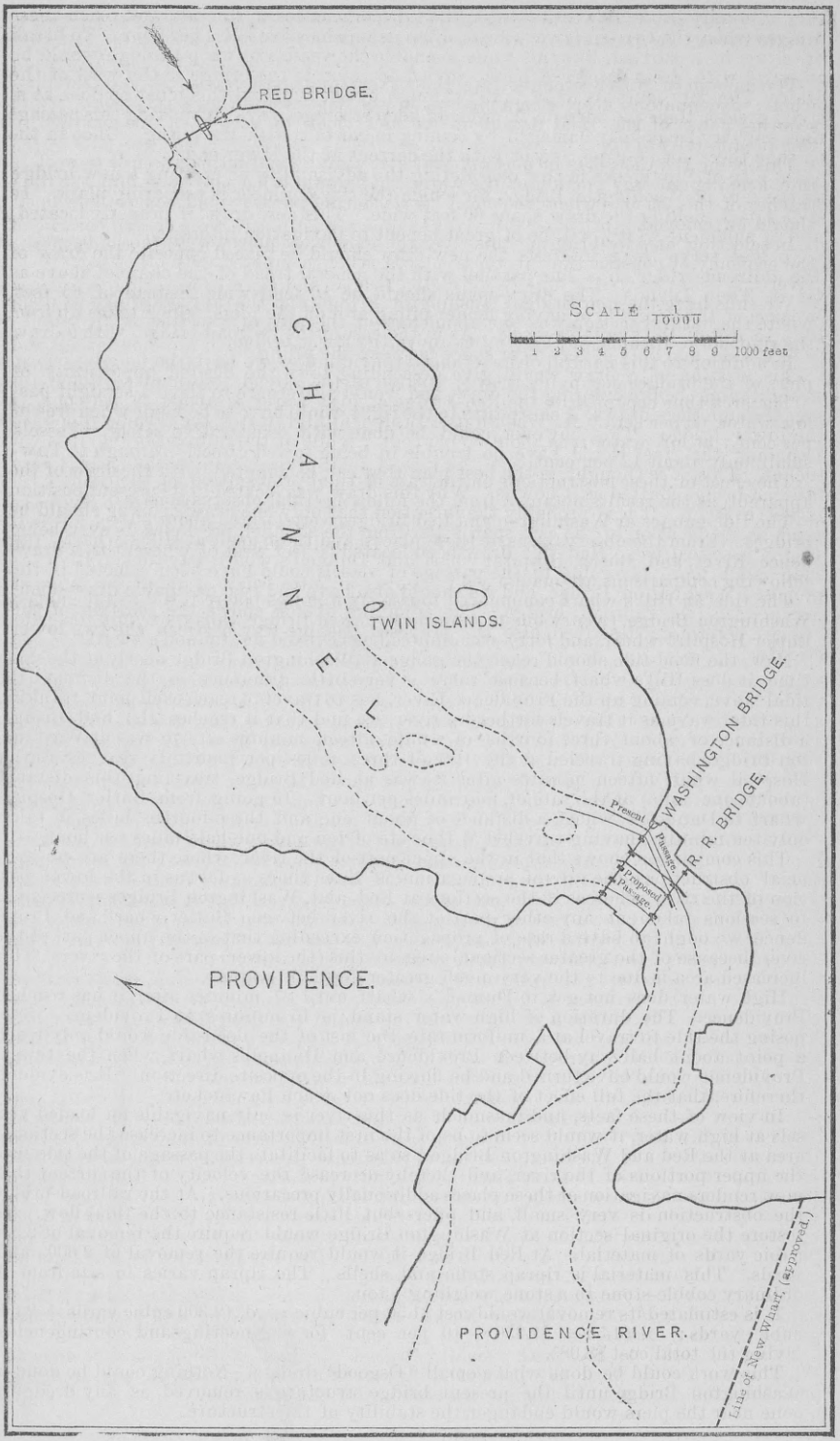
To facilitate the passage of vessels through this and Washington Bridge, double lines of piling have been put in between the draws of the two bridges. This piling has been extended about 300 feet above Washington Bridge, and one line has been extended about the same distance below the railroad-bridge. The space between these lines of piles varies from 38 to 60 feet. Vessels going up the river enter this passage at an angle with the current, and pass the railroad-bridge at an angle of 20° with the axes of the piers. When they reach Washington Bridge a turn must be made to the left of about 45°. This turn has to be in the draw of the bridge, where the passage is only 38 feet wide. These vessels pass up the river at high water, when there is but little current. They cannot tow through safely, because of the sharp turn above alluded to, but have to warp through, and make up the tow above. In descending

they generally leave Pawtucket after the tide commences to run out, and reach these bridges when the current is very swift, often as much as five miles per hour. To break up a tow in a current like this so as to enable the vessels to warp through would be attended with great danger of being carried down on to the bridge to the west of the draw. The only course is to be taken through by the tug, and this must be done at a speed greater than the current, in order to keep steerage-way. In making this passage they are very frequently damaged by coming in contact with the piling. Once in the passage there is no escape, except with the current at the lower end.

The city of Providence is now considering the advisability of erecting a new bridge on the site of Washington Bridge, for which the city engineer is preparing plans. It is designed making the draw spans 60 feet wide. This new draw, if properly located, and of sufficient width, will be of great benefit to navigation interests.

To best serve these interests the new draw should be placed opposite the draw of the railroad-bridge in a line parallel with the general trend of the channel above as far as Twin Islands. The draw-spans should be 80 feet wide instead of 60 feet, because of the necessity of having fender-piling around the piers, which takes up from 10 to 15 feet of the available space. As in the case of the railroad-bridge, with a draw 60 feet wide, and only 47 feet clear space between the piling.

This location of a draw would give descending tows the desired opportunity of straightening before entering the draw, and would also secure to them a straight passage through these draws. A sharp turn to the right would have to be made when free of the lower bridge. This, however, could be done with comparative safety. Vessels ascending the river would have no trouble in being towed directly through to Pawtucket. This, it is thought, is the best plan that can be adopted, with the draw of the railroad-bridge located as it now is. Why this draw was located in its present position is not evident. It was probably the intention that only one draw-opening should be used, as the location of the east span, so far from the channel, precludes its ever being of any practical use. Had this draw been located 60 feet west of where it is, a draw-span much more favorable to the passage of vessels could have been selected in the proposed Washington Bridge, and we should also have had two navigable draw-openings in this (the railroad) bridge. The adjoining sketch shows the location of the bridges heretofore described, also the proposed passage-way between the two lower bridges.


RED BRIDGE.
SCALE 1/10000
1 2 3 4 5 6 7 8 9 1000 feet
CHANNEL
TWIN ISLANDS.
WASHINGTON BRIDGE.
R. R. BRIDGE
Present Passages.
Proposed Passages.
PROVIDENCE.
PROVIDENCE RIVER.
Line of New Wharf. (approved.)

OBSTRUCTIONS TO TIDAL FLOW AT BRIDGES AND IMPROVEMENTS REQUIRED THEREBY.

The amount of water brought into this river by its tributaries is very small and wholly inadequate to keep open a channel of the depth sought for navigation. To the scouring power of the tidal flow alone we must look to keep open this channel, and this it fails fully to do.

This being the case, it is important that everything obstructing the free flow of the tide, keeping out any portion of the water that would otherwise flow into the upper reaches of this basin, (where the effect as a scouring power would be most beneficial,) should be removed.

In selecting sites for bridging this river the narrowest places were chosen because of the economy of construction at these places, when compared with other parts of the river.

We thus have the Red Bridge, Washington Bridge, and the railroad-bridge at places where the natural section was but about half of the area of a section at any point of the river for a distance of three miles above the lower bridge.

In addition to this natural obstruction to the tidal-flow we have the foundations and piers of the bridges occupying a large portion of the already too small sectional area.

The area thus occupied by the Red Bridge at high water is about 49 per cent.; at low water, 66 per cent. At Washington Bridge, at high water, the area occupied is 44 per cent.; at low water it is about 55 per cent.; while at the railroad-bridge it is very small, only about 12 per cent.

The effect of these obstructions on the rate of tidal propagation in the river is very apparent, as the results obtained from the following tidal observations will show:

The tide-gauges at Washington and Red Bridges were located about 50 feet above the bridges. From the observations at these places, and those made at Hill's wharf, Providence River, and Butler Hospital wharf and Dunnell's wharf, Pawtucket River, the following comparisons are made:

The tide at Hill's wharf commenced to rise six minutes before it did at the gauge at Washington Bridge, twenty-one minutes before Red Bridge, thirty-six minutes before Butler Hospital wharf, and forty-six minutes before it did at Dunnell's wharf.

Now, the flood-tide should reach the gauge at Washington Bridge nearly at the same time it does Hill's wharf, because there is very little difference in the distance the tidal wave, coming up the Providence River, has to travel to reach each point. Taking this tidal wave as it travels farther up river, we find that it reaches the Red Bridge, a distance of about three-fourths of a mile, fifteen minutes after it was at Washington Bridge, having traveled at the rate of three miles per hour. It reaches Butler Hospital wharf fifteen minutes after it was at Red Bridge, traveling this distance (about one mile) at the rate of four miles per hour. In going from Butler Hospital wharf to Dunnell's wharf, a distance of about one and three-fourths miles, it takes only ten minutes, having traveled at the rate of ten and one-half miles per hour.

This comparison shows that in the upper part of the river, where there are no artificial obstructions, the rate of propagation is three times as fast as in the lower portion of the river, whereas if the sections at Red and Washington Bridges were equal to sections taken at any other part of the river between Butler wharf and Providence, we ought to have a rate of propagation exceeding that in the upper part of the river, because of the greater sectional area in this (the lower) part of the river. This increased area is due to the very much greater depth of water.

High water does not get to Dunnell's wharf until 27 minutes after it has reached Providence. The duration of high-water stand is 15 minutes at Providence. Supposing the tide to travel at a uniform rate, the last of the flood-tide would only reach a point about half way between Providence and Dunnell's wharf, when the tide at Providence would have turned and be flowing in the opposite direction. It is evident, therefore, that the full effect of the tide does not reach Pawtucket.

In view of these facts, and inasmuch as this river is only navigable for loaded vessels at high water, it would seem to be of the first importance to increase the sectional area at the Red and Washington Bridges, so as to facilitate the passage of the tide into the upper portions of the river, and thereby decrease the velocity of the current that now renders navigation at these places additionally precarious. At the railroad-bridge the obstruction is very small, and offers but little resistance to the tidal flow. To restore the original section at Washington Bridge would require the removal of 2,300 cubic yards of material. At Red Bridge it would require the removal of 2,600 cubic yards. This material is riprap stone and shells. The riprap varies in size from an ordinary cobble-stone to a stone weighing $\frac{1}{2}$ ton.

It is estimated its removal would cost $1.50 per cubic yard, (2,300 cubic yards + 2,600 cubic yards;) × $1.50 = $7,350 + 10 per cent. for engineering and contingencies, giving the total cost $8,085.

This work could be done with a small "Osgood" dredge. Nothing could be done at Washington Bridge until the present bridge structure is removed, as any dredging pone near the piers would endanger the stability of the structure.

As to who should bear the expense of doing this work it is not for me to say. That this work if done would effect a more permanent improvement than the dredging of shoals, as estimated for on pages 5 and 6 of this report, I do not doubt.

If both could be accomplished the wants of the navigation interests of the river would be fully met. The estimated cost of both improvements is $14,619.

The number of vessels towed to Pawtucket during 1873 was 420; with cargoes consisting principally of coal and lumber.

The early history of the bridges I obtained from a pamphlet written on them by Col. J. Albert Monroe. I was assisted in the survey by Mr. W. P. Jewett, civil engineer. The work of dredging was under the direct superintendence of Mr. G. N. Weaver, civil engineer.

Respectfully submitted.

H. A. BENTLEY,
Civil Engineer.

Bvt. Maj. Gen. G. K. WARREN,
Major Engineers, U. S. A., Newport, R. I.

Record of tide-gauge kept at Hill's wharf, Providence, by the City Water-Works, from May 22 to December 28, 1873.

[The observations were taken with a self-registering tide-gauge furnished by the United States Coast Survey.]

Date.	Number of high water.	Total high water.	Number of low water.	Total low water.	Notes.
May 22 to 31, 1873	17	139.51	18	57.86	
June 1 to 30, 1873	56	451.58	55	200.46	
July 1 to 31, 1873	60	486.23	60	216.95	
August 1 to 31, 1873	56	442.51	56	191.96	Two days lost.
September 1 to 30, 1873	58	467.20	58	197.97	
October 1 to 31, 1873	60	497.95	60	215.83	
November 1 to 30, 1873	58	455.23	58	192.59	
December 1 to 28, 1873	48	375.74	49	167.76	Four days lost.
	413	3,315.95	414	1,441.38	

1441.38 ÷ 414 = 3.481, mean low water.
3315.95 ÷ 413 = 8.029, mean high water.
8029 − 3.481 = 4.548, mean rise and fall of tide.

Record of tide-gauge kept at Bishop's Point, Pawtucket River, Rhode Island, in October and November, 1872.

Date.	High water.	Low water.	Date.	High water.	Low water.
October 13	7.6	1.1	October 28	6.8	2.0
14	7.6	1.4	29	5.8	2.0
15	6.9	1.6	30	6.8	2.2
16	7.7	1.8	31	7.7	1.9
17	7.7	1.6	November 1	7.9	2.0
18	7.7	1.5	2	7.0	1.8
19	7.0	1.6	3	7.8	1.8
20	7.0	1.6	4	7.5	1.8
21	6.5	2.0	5	7.2	1.7
22	5.9	2.1	6	7.7	1.7
23	5.6	2.2	7	7.2	2.7
24	5.6	1.6	8	6.6	1.8
25	5.7	1.9	9	6.0	1.8
26	5.8	1.7	10	6.7	2.0
27	5.9	1.6			

Whole number of days observations were made, 29. Mean high water, 6.85 on gauge; mean low water, 1 81 on gauge; mean rise and fall, 5.04 feet. Lowest tide below mean low water, 0.71 feet; highest tide above mean high water, 1.05 feet.

Record of tide-gauge kept at Butler Hospital wharf, Pawtucket River, Rhode Island, in April and May, 1873.

Date.	High water.	Low water.	Date.	High water.	Low water.
April 22	5.5	1.0	May 6	4.6	0.9
23	5.7	0.5	7	4.9	1.1
24	6.2	0.3	8	5.0	0.8
25	5.7	0.1	9	5.25	0.8
26	5.6	0.0	10	4.9	1.1
27	5.6	0.1	11	5.3	0.6
28	5.3	0.05	12	5.5	0.8
29	5.5	0.4	13	5.6	1.1
30	5.4	0.1	14	4.8	0.8
May 1	4.2	0.3	15	5.4	0.9
2	4.5	0.9	16	5.1	0.85
3	4.8	1.0	17	5.2	1.0
4	4.8	0.7	18	4.6	1.3
5	4.1	0.6	19	4.7	0.7

Whole number of days observations were made, 28. Mean high water, 5.13 on gauge; mean low water, 0.67 on gauge; mean rise and fall, 4.46 feet. Lowest tide below mean low water, 0.67; highest tide above mean high water, 1.07.